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PROJECT NO. 23833

OU 7-13/14 In Situ Grouting Project Grout Selection Basis

Idaho National Engineering and Environmental Laboratory

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ACRONYMS

ASTM	American Society of Testing and Materials
COC	contaminant of concern
EDF	engineering design file
INEEL	Idaho National Engineering and Environmental Laboratory
ISG	in situ grouting
LLW	low-level waste
RWMC	Radioactive Waste Management Complex
SDA	Subsurface Disposal Area
TRU	transuranic

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OU 7-13/14 In Situ Grouting Project Grout Selection Basis

1. PURPOSE

This engineering design file (EDF) provides the design parameters for grout to perform in situ grouting (ISG) of both transuranic (TRU) and low-level waste (LLW) pits and trenches at the Subsurface Disposal Area (SDA) at the Idaho National Engineering and Environmental Laboratory's (INEEL's) Radioactive Waste Management Complex (RWMC).

This EDF summarizes the information provided in the draft EDF, "In Situ Grout Selection Criteria and Recommendation for Foundation and Contaminant Grouting of LLW and TRU Pits and Trenches." It also presents the information in a form consistent with the other EDFs of the conceptual design report for the ISG Project. A detailed grout evaluation should be completed as specific waste areas requiring grouting are identified.

2. BACKGROUND

Generally, LLW trenches and pits within the SDA at the RWMC will be grouted to form a monolith totally encapsulating the waste. Transuranic pits and selected trench areas will be grouted with a wider spacing of columns sufficient to support a cap (see EDF-5028, "RWMC In Situ Grouting Project—Foundation Grouting Study").

The LLW waste under consideration lies beneath an area of about 11.1 acres and occupies a volume of about 1,320,000 ft^3. The TRU pits and trenches are spread over an area of 15.4 acres and occupy a volume of about 2,330,000 ft^3.

In situ grouting involves underground injection of Portland cement-based grout or other material that will solidify after placement. Grout injected in the foundation mode will support a cap that will stop water intrusion and thus slow contaminant release and movement. Grout injected to slow contaminant release provides a chemical environment to decrease the release of U, Tc-99, and I-129 from LLW. The contaminant release mode grout provides a physical and chemical environment that deceases the release of U, Tc-99, and I-129 from the LLW.

The draft EDF, "In Situ Grout Selection Criteria and Recommendation for Foundation and Contaminant Grouting of LLW and TRU Pits and Trenches," evaluates the effectiveness of grouts suitable to support a cap and treat the LLW buried at the SDA. While grouting can be accomplished by way of several in situ methods, it has been determined by previous studies that in situ jet grouting is most appropriate for the SDA.

In situ jet grouting uses a specially designed drill rig to deliver and intimately mix grout with soil, debris, and contaminants in the subsurface. The grout is injected at high pressures (i.e., 4,000 to 10,000 psi) through small nozzles. This high pressure, combined with the dense grout, provides the energy required to mix the grout and subsurface materials (i.e., soil and waste). Each injection of grout forms a cylinder, and a series of interconnected columns is used to form a continuous monolith.

A triangular pitch describes the spacing between holes for grouting a given area. When drawing a line between the adjacent holes, a series of interconnected triangles are formed. The jet grouting process is accomplished either to form a monolith or columns. If the columns are on a tight enough triangular pitch matrix (i.e., 2 ft on center) to assure debris waste is filled, a continuous monolith is formed. This is especially true with injection of grout in nonhomogenous waste depending on voids and types of containers. Injections on a wider pitch (i.e., 6 to 15 ft on center) can give sufficient columns to support a cap in regions of buried waste of uncertain density and void space.

Grouts must be specially designed for ISG implementation. This requires liquid material to meet the viscosity, particle size, and set times required for effective operation of the high-pressure injected grouting process. Constraints of jet grouting in buried waste of radiologically contaminated material impose additional constraints beyond normal construction jet grouting, particularly in the area of returns (i.e., the grout that comes to the surface in each grout injection).

In addition to the required grout specifications, actual field test grouting of identified products has been shown to be a critical step in grout verification. Past bench- and field-scale testing in simulated buried waste and/or actual contaminated soil have demonstrated the feasibility of two organic and five cementitious grouts. These field tests demonstrated ISG application to surrogate buried waste matrices similar to those found in the TRU pits and trenches (Pits 1 through 6 and 9 through 12 and Trenches 1 through 10). One field test successfully applied grout to contaminated soil at a location in the SDA known as the Acid Pit. References documenting these field tests are included in the draft EDF, "In Situ Grout Selection Criteria and Recommendation for Foundation and Contaminant Grouting of LLW and TRU Pits and Trenches."

3. SCOPE

This EDF is limited to presentation of the parameters that must be included in specifications for grout for the ISG Project.

4. REQUIREMENTS (FUNCTIONAL, PERFORMANCE, AND TECHNICAL)

4.1 General

- Field implementability—Grouts must have been demonstrated operationally feasible in a full-scale/production operation or have the appropriate properties and laboratory test to indicate they are implementable.

- Low temperature of set—Grouts must have a set temperature less than 100°C. Grouts that produce temperatures higher than the boiling point of water could produce steam, leading to mass expulsion during the curing process. Even temperatures under 100°C need to be minimized to reduce the chance of cracking and shrinking as the cement sets, especially in bulk emplacement.

- Minimize contaminant release during ISG—The liquid grout that might return to the surface during the emplacement process must minimize contaminant release to the environment during the grouting operation and while setting.

4.2 Foundation Grout

The foundation support ISG primary objective is to support the cap. The resultant grout/waste support columns must exhibit the following attributes to support the cap during design life:

- Compressive strength—The grout columns must have sufficient confined compressive strength to support the weight of the cap, overburden, grouted waste, and any equipment required to construct the cap. An ISG column is expected to be a heterogeneous mixture of pockets of grout, grout mixed with soil, soil, and some waste. The injected grout mixture will stabilize buried waste by filling voids in the waste and associated soils and provide a grout/waste column to prevent subsidence.

- Durability—The support columns must retain their compressive strength during the expected life of the cap. The design life for the cap has not yet been defined. However, it is expected to be a longer than 100 years.

- Grout/waste compatibility—The grout must be compatible with the soil and waste matrix. Transuranic waste matrices, such as nitrate salts and organic sludges, and LLW matrices, such as ion exchange resins, in sufficient amounts when mixed with some Portland cement-based mixtures may interfere with grout curing. Areas that have these types of wastes may require a different grout mixture. The locations of these types of wastes can be found in the disposal records and summary reports of these records for the SDA.

Foundation support ISG is not intended to change the physical or chemical form of the LLW, though it should not negatively affect transport.

4.3 Contaminant Migration and Encapsulation In Situ Grout

The primary objective is to chemically and physically reduce contaminants, specifically U, I-129, and Tc-99 from their potential to migrate. This will contribute to reduce the risk posed by U, Tc-99, and I-129. Contamination control ISG is intended to change the chemistry of the system along with decreasing water contact. This is accomplished physically by decreasing the bulk permeability and increasing the bulk density of the existing buried waste site, and chemically by additives that change the solubility. Both factors limit release and transport of Tc-99, U, and I-129. Specific criteria are:

- Control contamination—The grout and LLW form should effectively minimize mobility of contaminants of concern (COCs).

- Encapsulate contaminants—The grout material should encapsulate the waste components and prevent release of COCs.

- Monolith durability—The grout and LLW form contamination control should last for an extended period of time. However, this time period has not been defined, and testing to verify durability for a sufficient time period is impossible. Monolith durability will have to be determined by comparing the test area monolith physical properties, such as compressive strength and density, to other durable natural materials, such as rock and soil.

- Grout/waste compatibility—The grout must be compatible with the soil and waste matrix. Transuranic waste matrices, such as nitrate salts and organic sludges, and LLW matrices, such as ion exchange resins, in sufficient amounts when mixed with some Portland cement-based grouts may interfere with grout curing.

- Physical stability—The injected grout mixture will stabilize buried waste by filling voids in the waste and associated soils, preventing subsidence.

- Monolith chemical buffering—Some grout materials affect the leach water chemistry and contaminant solubility by chemical buffering, lowering the oxidation-reduction potential (Eh), and/or raising the pH of groundwater within the monolith. Such chemical changes reduce contaminant solubility and mobility.

- Decrease in hydraulic conductivity—Though the cap will be the main feature for preventing water intrusion, it is expected that the injected grout will mix with the buried waste and soils to lower its bulk permeability.

5. SYSTEM CLASSIFICATIONS, CATEGORIZATIONS, AND DETERMINATIONS

5.1 Safety Classification and Natural Phenomena Hazard Category

The grout safety category is consumer grade. Natural phenomena are not directly applicable to the grout.

6. ASSUMPTIONS

It is assumed that both the foundation grout and the contaminant-control grout will be supplied by a subcontractor and will be Portland cement based.

7. DESIGN CRITERIA

7.1 Applicable Design Codes and Standards

No design codes or standards are mandatory for the in situ grouts. However, the following standards may be used to ensure the quality of the grout production:

American Society for Testing and Materials (ASTM):

ASTM C 31, *Standard Practice for Making and Curing Concrete Test Specimens in the Field*

ASTM C 33, *Standard Specification for Concrete Aggregates*

ASTM C 39, *Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens*

ASTM C 94, *Standard Specification for Ready Mixed Concrete*

ASTM C 138, *Standard Test Method for Unit Weight, Yield, and Air Content (Gravimetric) of Concrete*

ASTM C 150, *Standard Specification for Portland Cement*

ASTM C 172, *Standard Method of Sampling Freshly Mixed Concrete*

ASTM C 192, *Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory*

ASTM C 231, *Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method*

ASTM C 494, *Standard Specification for Chemical Admixtures for Concrete*

ASTM C 618, Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete

National Ready Mixed Concrete Association:

Certification of Ready Mixed Concrete Production Facilities (checklist with instructions).

Other standards may be applicable depending on the specific grout mixture proposed by the subcontractor.

7.2 System Design Requirements

Testing of the in-place hardened grout/waste/soil mixture in the SDA will not be practical because of concerns with contamination release and safety. Therefore, quality control testing for the grout will be based on a test of representative samples of the grout as it is produced and field tests of the ISG in cold test locations outside the SDA.

Some of the tests recommended for grout during production are temperature, unit weight, and air content. Samples should also be taken for compressive strength testing. These tests will help ensure that the requirements of Section 4 are met.

The batch plant that produces the grout should be certified to a standard, such as the one indicated in Section 7.1.

It is recommended that raw material used for grout meet ASTM standards, such as the ones presented in Section 7.1.

The subcontractor shall be required to submit a quality control plan that indicates the tests and procedures that he proposes to use to ensure the grout will meet performance requirements.

7.3 Grout Properties

The grouts must have the viscosity, particle size, and set times required for grouting operations. The viscosity is important for pumping and jetting into the waste zone. It is also important in relation to plugging of hoses or piping. The particle sizes need to be small in order to go through the jets. Set time is important to avoid plugging of the systems.

Normal Portland cement-based jet grouts are mixtures of just cement and water. Fly ash and chemical admixtures are sometimes added to enhance the mixture. The admixtures are added to increase viscosity and to reduce and decrease set time. Other materials that may be added include silica fume, ground blast furnace slag, and fine sand. These materials may be added to enhance the strength at lower cost or to provide other properties. G-ment, a proprietary grout mixture that includes some of the previously mentioned materials, has been studied at the INEEL. It and other grout mixtures are discussed in more detail in the draft EDF, "In Situ Grout Selection Criteria and Recommendation for Foundation and Contaminant Grouting of LLW and TRU Pits and Trenches."

A generic high quality grout is 80% solids by weight and has a nominal set time of 10 to 24 hours before jetting into the soil, and a set time of 30 to 60 minutes after mixing with the soil.

The ability of the grout to resist deformation and subsidence is typically measured through compressive strength. The Nuclear Regulatory Commission has required a minimum compressive strength of 60 psi to support 20 ft of overlying soil. The minimum 28-day compressive strength for the contamination control grout should be at least 500 psi to ensure the in-place strength, when mixed with the waste and soil, is at least 100 psi. The foundation support grout should have a minimum 28-day compressive strength high enough to have an in-place compressive strength of 1,200 psi.

Compressive strength is also related to the adhesion of the grout to waste, hydraulic conductivity, and durability. Generally, the higher compressive strength indicates better adhesion, lower hydraulic conductivity, and better durability.

Several grouts have been previously tested at the INEEL. Most of them had the properties necessary to meet minimum requirements (see the draft EDF, "In Situ Grout Selection Criteria and Recommendation for Foundation and Contaminant Grouting of LLW and TRU Pits and Trenches," for additional discussion of grout properties).

8. RISKS

The major risks for grout are in relation to its ability to be placed in the SDA over a large area in an efficient manner. The grout must be produced in large quantities, but no more than can be used before it starts to set. Changes in temperature may affect the grout properties. It may be necessary to adjust the grout mixture to account for field conditions.

Jet grouting requires the grout to be pumped through small nozzles. The grout must remain fluid from the time it is mixed until it is in place. Problems that could cause plugging of the grout lines or nozzles include the following:

- Loss of grout fluidity because of high temperature conditions
- Loss of grout fluidity caused by delays in its placement
- Poor design of the piping or hoses used to pump the grout
- Introduction of rocks, hardened grout, or other materials into the grout.

There will be risks related to the cost and quantity of the grout to be used. It is difficult to estimate the quantity of grout necessary because of the variations in depth to rock, the amount of void space, and the amount of grout that will come to the surface. It may be best to bid the grout on a cost per yard placed in the SDA basis to mitigate this risk.

9. LOGISTICS SUPPORT

Grout production requires a batch plant located either at the INEEL or at a town near enough to transport the grout without adverse effects because of time. If the batch plant is located at the INEEL, water, power, and facilities for personnel, such as restrooms and lunchrooms, must be provided. The batch plant location must also accommodate the transport and unloading of the raw materials, such as cement necessary for the grout production.

10. RESULTS, CONCLUSIONS, AND RECOMMENDATIONS

The lowest cost Portland cement-based grout that can be successfully jet grouted is recommended for use as the foundation support grout. This is likely to be a cement and water grout with admixtures to increase viscosity and increase set time. The specification for the materials should be a performance type that gives the requirements and verifies compliance based on field tests in a cold test area outside the SDA.

For contamination control monolithic encapsulation of LLW, all Portland cement-based grouts provide some benefit. Based on preliminary results, grouts containing ground blast furnace slag and silica fume, in addition to cement, should be superior to other INEEL-tested grouts, based on specific Tc-99 contaminant containment. It appears that the reducing properties from ground blast furnace slag are the key to contamination control for LLW specific contaminates. It is recommended that a performance-type specification requires that the grout contamination control grout be used, requiring the use of ground blast furnace slag in a Portland cement-based grout.

Detailed grout evaluations should be performed based on the area specific wastes and site conditions. These evaluations should be completed as specific waste areas requiring grouting are identified.

11. REFERENCES

ASTM C 31, *Standard Practice for Making and Curing Concrete Test Specimens in the Field.*

ASTM C 33, *Standard Specification for Concrete Aggregates.*

ASTM C 39, *Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens.*

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Certification of Ready Mixed Concrete Production Facilities (checklist with instructions)

EDF-5028, "RWMC In Situ Grouting Project—Foundation Grouting Study."